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A PROCEDURE TO MODIFY HABITAT SUITABILITY INDEX MODELS

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Habitat Suitability Index (HSI) models are used frequently in environmental impact studies to evaluate the quality of habitat for wildlife. Because HSI models are usually constructed for use throughout a species' entire range, models often must be modified to perform adequately in the area being evaluated. This paper presents a procedure for modifying HSI models to improve their performance.

The study was conducted at the Oak Ridge National Laboratory near Oak Ridge, Tennessee, in 1981–1982. Our work involved evaluation and modification of draft HSI models for 6 species. The model for the hairy woodpecker (*Picoides villosus*) will be used to illustrate the modification procedure and to demonstrate the logic and decision-making needed to evaluate and improve the performance of an HSI model.

BACKGROUND

The model was evaluated by comparing its output with ratings assigned to 40 forested sites by 6 people considered to be authorities on the habitat requirements of the hairy woodpecker. Study sites were selected to provide a range of conditions for each variable in the model. Species composition, stand condition, and size class varied among sites. Sites were approximately 0.25 ha in size.

The experts were asked to rate potential habitat quality of each site from 0 (unsuitable) to 1.0 (optimal) based on their experience and knowledge of habitat requirements of the hairy woodpecker. Scores were assigned independently and later averaged to provide a measure of the quality of each site. Each expert also provided a written explanation of how his or her score was determined for each site. This information provided clues for improving the model's performance.

After obtaining the experts' scores at each site, we measured the variables contained in the model, plus other variables that we thought might be important. Field data were converted to Suitability Index (SI) values according to the curves in the draft model, and an HSI was calculated for each site. Our goal in the modification process was to produce a model that would generate HSI values that were the same as those assigned by the experts.

The draft model (P. J. Sousa, U.S. Fish and Wildl. Serv., unpubl. doc.), which had received no previous review or testing, contained 5 variables (Fig. 1a–e) that described habitat requirements over the entire range of the hairy woodpecker. Three variables (V1–3: density of snags, size of overstory trees, and abundance of spruce in the overstory) were intended to evaluate a forest's potential to furnish suitable nesting sites, and were used to calculate an SI for reproduction (SIR). The other 2 variables (V4–5: size of overstory trees and tree canopy closure) were used to calculate an SI for both

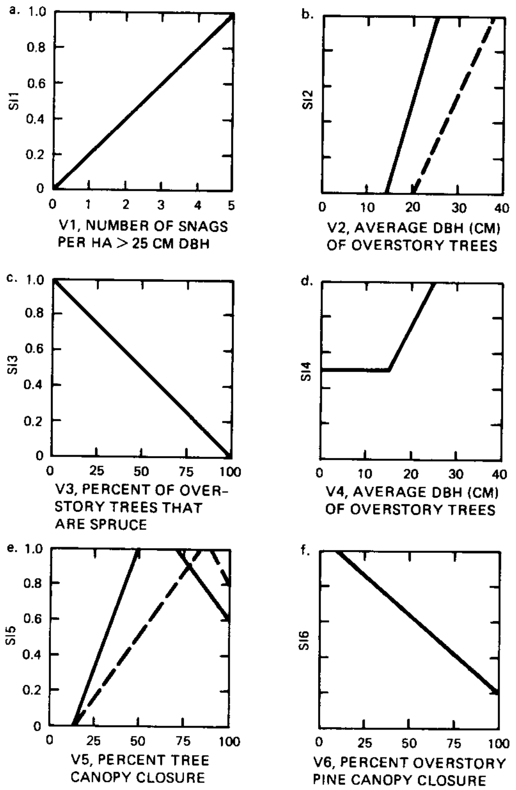

Fig. 1. Variables and suitability index (SI) curves in the draft and modified Habitat Suitability Index model for the hairy woodpecker. Variables 1–5 were in the draft model and 6 was added during the modification process. Dashed lines show modifications to the original curves.

cover and foraging (SIC), which modified the reproductive value. Equations were

$$SIR = SI1 + (SI2 \times SI3), \text{ not to exceed } 1.0$$

$$SIC = (SI4 \times SI5)^{1/2}$$

$$HSI = SIR \times SIC.$$

ILLUSTRATION

We first evaluated the performance of the draft model by generating a scatterplot of the mean score assigned to each study site by the species experts and the score generated by the model. A perfect model performance would have resulted in a correlation of 1.0, a slope of 1.0, and an intercept of 0.0. The plot revealed that the model scored all sites high (>0.75), whereas the experts recognized a much wider range of habitat quality (0.13–0.97). The correlation ($r = 0.07$, $P > 0.50$) indicated that the draft model was not a good predictor of habitat suitability for hairy woodpeckers on our study area.

Our next step was to compare, by correlation analysis, the experts' scores with the field data for each variable (e.g., V1, number of snags per ha) to identify those with the most influence on the experts' scores. Only V2 was significantly correlated with the experts' ratings ($r = 0.67$, $P < 0.001$). Written comments from the experts indicated that V1 was also an important consideration in their suitability ratings. Because spruce (*Picea* spp.) did not occur on our sites, we had no way to determine the effect of V3. Regressions were run using the SI's for each variable and for each of the life requisites in the model.

The first modification was to redraw the SI curve for V2 as shown in Fig. 1b. This change was supported by the experts' comments and was a step that we knew would result in lower model scores.

The second modification was to increase the importance of SI1. In the draft model, an area without any snags could receive an HSI of 1.0 if overstory trees were large enough for SI2 to be at its maximum. This compensatory relationship had not been reflected in the experts' scoring. Their average score on sites without snags was never higher than 0.85, even when tree diameters were large. Most sites with these characteristics were scored 0.7–0.8 by the experts; therefore, we modified the reproductive equation as follows:

$$SIR = SI1 + \left(\frac{3SI2}{4} \times SI3\right)$$

not to exceed 1.0.

The effect of this modification was to limit SI2 to a maximum of 0.75. Therefore, to obtain an SIR between 0.76 and 1.0, a site would have to have either large snags or both large-diameter trees and snags. The correlation between this modified model (M1) and the experts' scores was $r = 0.36$ ($P < 0.05$). This performance was considerably better than the original model, but still not acceptable.

The next step was to examine a scatterplot of M1 vs. the experts' scores to see which sites deviated from the expected linear relationship. We then examined the experts' written comments about each site and our own field notes which contained detailed site descriptions. We found that many outliers were sites dominated by pines (*Pinus* spp.). We had gathered data on the percentage of pine in the overstory at the time we made site measurements; therefore, we calculated the correlation between the percentage of pine and the experts' scores and found a strong negative relationship ($r = -0.91$, $P < 0.001$).

Although hairy woodpeckers commonly use stands of pines in the West, the experts indicated by their scoring and comments that the presence of pines lowers habitat quality in eastern forests. Therefore, we developed a suitability curve for a new variable (V6) (Fig. 1f) and incorporated it into the cover portion of a new model, M2. Thus the new equation was $SIC = (SI4 \times SI5 \times SI6)^{1/3}$. The correlation between M2 and the experts' scores ($r = 0.63$, $P < 0.001$) indicated substantial improvement in the model.

Although M2 performed reasonably well, it still produced scores that were high relative to the experts' ratings. We addressed this problem by changing the mathematical function used to calculate the SIC. The draft model had used a geometric mean of SI4 and SI5, implying a compensatory relationship between the variables. Based on the experts' scoring, we concluded that high SI's for all variables were needed for optimum habitat quality. Therefore, we replaced the geometric mean in M2 with a product: $SIC = SI4 \times SI5 \times SI6$, and noted that the new model, M3, performed considerably better ($r = 0.80$, $P < 0.001$).

The final modification was to revise the graph for tree canopy cover (Fig. 1e). This increased the HSI scores on several sites that had been rated highly by the experts and had closed, or nearly closed, canopies. The experts believed that a dense canopy improved woodpecker habitat by promoting a more open midstory. The correlation obtained with this final version of the model (M4) was $r = 0.82$ ($P < 0.001$).

We were not able to effect any other improvements that could be supported either by the literature or by conversations with the experts. The correlation between HSI values predicted by the final model and the experts' scores was greatly improved over that of the original draft model. On 85% of the sites, the difference between the experts' ratings and M4's output was ≤ 0.2. Given the difficulty of scoring an intangible characteristic such as habitat quality on a scale of 0 to 1.0, we considered this to be an acceptable performance of an HSI model.

DISCUSSION

Given the widespread use of HSI models in land management, environmental impact assessment, and mitigation planning, it is important to evaluate the reliability and applicability of the models. Use of the procedure we followed (summarized in Appendix A) can provide the project biologist or manager with reliable analytical tools to help guide land use decisions. Any standard of comparison available to the user and appropriate to the model can be used. The standard of comparison selected and the validity of its relationship to true habitat quality is critical.

To evaluate an HSI model, it is important to use as many study sites as possible that represent a variety of habitat conditions. This is essential because a model should perform well throughout the range of habitat quality it is expected to portray. Modification should be based on a test in the area where the model is to be applied. As we found in our work with the hairy woodpecker, geographic differences in habitat preferences can lead to changes in a model.

If a field test is not possible, an office exercise based on information from the literature and the opinions of local biologists can be used as a basis for modification. However, in the absence of an actual field test, model reliability will not be known.

Modifications to a model should be biologically sound and easily explainable. Changes that improve correlations between a model and a standard of comparison, but cannot be justified biologically, should not be made. If there is more than 1 way to achieve the same result, then the alternative that is easiest to understand and apply should be used. For example, changing the weighting of a variable may have the same effect as changing the slope of that variable's suitability curve; the latter might be preferred because the variable would be easier to understand.

If a complicated model performs poorly, it may be best to start over and develop a simplified model that incorporates only the 2 or 3 most important variables. In general, the larger the number of variables, the less responsive the model is to changes in any 1 graph or equation.

Although we accomplished our objective of improving a literature-based HSI model, we recognize that the model has not been fully validated. The next step would be an evaluation in another portion of the species' range using another data set or standard of comparison.

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Appendix A. Procedure used to evaluate and improve HSI model performance.

1. Select study sites in the location and cover types in which the model is to be applied.
2. Select an appropriate standard of comparison.
3. Collect data.
   a. Collect data to be used as the standard of comparison.
   b. If necessary, convert standard to an index on a 0 to 1.0 scale.
   c. Collect field data for input into the model, using variables in the draft model and others that logically might be included.
   d. Calculate SI and HSI scores for each study site.
4. Perform diagnostics.
   a. Determine the correlation between model output and the standard of comparison.
   b. Examine a scatterplot for patterns and outliers.
   c. Determine the correlation between individual variables and the standard of comparison.
   d. Run regressions with the standard of comparison and the SI's, and with the life requisite SI's.
   e. Examine scatterplots from c and d above to determine if slopes and intercepts are appropriate.
5. Modify the model as appropriate.
   a. Add or delete variables.
   b. Modify SI graphs.
   c. Change weights of the SI's in the equation(s).
   d. Change mathematical relationships among SI's.
6. Document modifications and the justification for each.